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ABSTRACT

This paper details how memory protocols obtained in individual interviews may be translated to scores on several dimensions suggested by White. White's nine dimensions are: (1) extent, (2) precision, (3) internal consistency, (4) accord with reality, (5) variety of types of element, (6) variety of topics, (7) shape, (8) ratio of internal to external associations, and (9) availability. Following a description of how the interviews of 28 science graduates, ages 20 to 27, enrolled in the Diploma of Education program at Monash University, were conducted, the process of translation is described, difficulties are identified, and options discussed. The next section considers the results, in which consistent traits of individuals are identified. The following section discusses the level of knowledge displayed by the people interviewed, and comments on implications this has for education. (PN)

Converting Memory Protocols to Scores on Several Dimensions

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Paper given at the meeting of the Australian Association for Research in Education, Sydney, November 1980

CONVERTING MEMORY PROTOCOLS TO SCORES ON SEVERAL DIMENSIONS

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Cognitive structure is an important but nebulous construct in the theory and practice of learning. White (1979) argued that to achieve clarity in its definition one must specify a number of dimensions, and suggested a set of nine to initiate discussion. White also considered how several existing methods of investigating cognitive structure illuminate these dimensions, but his discussion remained general and did not get to details of how the information obtained by any of these techniques could be translated to scores on any of the dimensions. The present paper details how memory protocols obtained in individual interviews may be translated to scores on several of White's dimensions. Following a description of how the interviews were conducted, the first substantive section describes the process of translation and identifies difficulties and discusses options. The second section considers the results, in which consistent traits of individuals are identified. The third section discusses the level of knowledge displayed by the people interviewed, and comments on implications this has for education.

Conduct of Interviews

The two authors shared the interviewing task. In total they saw 28 science graduates, of ages 20 to 27, who were enrolled in the Diploma of Education program at Monash University. Each respondent was asked about two topics, first electric current and then, immediately following, eucalypts. These topics were chosen because they were thought to be subjects on which the graduates would be moderately well-informed, and because they were unrelated. The lack of relation was necessary because one purpose of the study was to see whether there were consistencies across topics in individuals' standings on many of these dimensions.

The lengths of the interviews depended on how much the respondents knew. For the two topics combined they ranged from 25 minutes to 75 minutes.

Each respondent was told that the purpose of the study was to see how people arranged knowledge in memory, and that they would be asked to tell all they knew about two topics. They were asked if they minded the interview being recorded, and were assured that the recordings would be anonymous.

They were first asked, "What can you tell me about electric current?" This question prompted from 3 to 20 statements. When the respondent indicated that nothing more was coming to mind, the interviewer asked "Do you have any personal experiences relating to electric current?" and then, later, "Do you have any mental pictures relating to electric current?" These three questions were designed to elicit three types of element in cognitive structure, which Gagné and White (1978) called propositions, episodes, and images. Next, the same three questions were asked about resistance, potential difference, Ohm's Law, charge, insulators, batteries, AC, and DC, which were chosen as important concepts in electricity. The interview then became more specific. The respondents were asked what they knew about formulae and definitions involving electric current, things they saw as similar or analogous to electric current, properties of electric current, its production, its uses and effects, its measurement, types of electric current, the history of electric current, and whether they recalled any incidents in films or books in which electric current played a major part. Finally they were asked whether anything else about electric current had occurred to them. Much the same procedure was then followed for eucalypts.

The respondent's share of the interview was then transcribed as a set of distinct propositions, images, and episodes.

Translation of Protocols to Scores on Dimensions

White's (1979) nine dimensions are:

1. Extent, how much the person knows of a topic.
2. Precision, how clear and complete each element of memory is.
3. Internal consistency, whether there are contradictions in the person's knowledge.
4. Accord with reality or generally accepted truth, what one might call the accuracy of the knowledge.
5. Variety of types of element, the relative proportions of propositions, images, and episodes.
6. Variety of topics, the range or diversity of the person's knowledge.
7. Shape, a difficult dimension to define but which refers to the pattern and degree of association among the elements of knowledge.
8. Ratio of internal to external associations, the proportion of associations which involve concepts that are judged to be an integral part of the topic as contrasted with those that may be seen as more general or more belonging to another topic.
9. Availability, the ease with which knowledge is recalled.

Extent. The extent score was taken as the total number of propositions, images, and episodes, whether accurate or not.

Precision. Each proposition was scored as vague or precise. This has to be subjective, and perhaps should be checked by the degree of agreement among independent observers. In this study, which to some degree must be regarded as a preliminary effort, we merely discussed any difficult cases and made a joint decision. The precision score was taken to be the fraction of the total number of propositions which was accepted as precise.

Internal consistency. Our intention was to score internal consistency as 1 minus the fraction of the number of conflicting pairs of propositions divided by the total number of propositions. However, only two pairs of conflicting statements were observed, so nearly everyone scored 1.00 on this dimension. This might not be the case with other groups of respondents or other topics.

Accord with reality. Each proposition was scored as correct or not. The authors, backed by reference texts, were thus the authority for "reality or generally accepted truth." There is as little difficulty in this as there is in scoring any factual test. The dimension score was calculated as the fraction which was scored correct of the total number of propositions.

Variety of types of element. The fractions of propositions, images, and episodes making up the total extent were calculated. Thus this "dimension" was represented by three scores. For most purposes that may be the most useful way of representing this aspect of cognitive structure. However, there may be some occasion on which a single score is required, so an index was invented equal to the reciprocal of the sum of the squares of the three fractions. This index takes its maximum value of 3 when there are equal numbers of propositions, images, and episodes, and its minimum of 1 when only one type of element is present.

Variety of topics. This dimension refers to a property of the total memory store, and cannot be assessed in this study where only two topics were sampled.

Shape. Experience gained in this study leads us to the view that White's (1979) initial postulation of this dimension left it rather vague, and that dividing it further may add to the clarity of the description of cognitive structure. Even further work is necessary; at present we identify only a dimension of linking. The derivation of scores on degree of linking and the trend of our thoughts about the rest of shape takes some space to describe.

The main concepts in the first proposition of a protocol are written on a sheet, and are joined by lines. For example, the proposition "Electric current is carried by charged particles" yields the concepts current, charge, and particle, which would be placed as a triangle with a line linking each pair. Subsequent propositions yield further concepts and linking lines. Any pair of concepts may be joined by any number of lines, depending on how many propositions they are mentioned in together. Images and episodes are then added, and are joined by lines to any concepts that they contain or refer to. In this way a map is constructed of each respondent's cognitive structure. Figure 1 is an example. This approach is a relatively simple means of obtaining a spatial representation of cognitive structure, but does rest on several debatable assumptions. The most central assumptions are that an array can represent the true nature of cognitive structure, and that using concepts as modes in the array is a valid way to represent the mode of storage in cognitive structure. As we are not satisfied with the present notion of shape these assumptions may be discarded in future work.

The pictorial form of these maps is interesting, but so far is not amenable to scoring. The numbers of concepts and links can be used to obtain an index of degree of linking, but the appropriate algorithm is not obvious. We chose the mean number of links per concept, but that turned out to be highly correlated with Extent, which may be a disadvantage. The point is discussed in the Results section below. Other aspects of shape besides degree of linking remain unscored.

Ratio of internal to external associations. All of a person's knowledge is a whole, but it is common for it to be conceived as being divided into topics. The concepts which were obtained in evaluating Shape can be classed as integral parts of the topic or as external to it. Thus battery,

charge, multimeter, superconductor, electron, shock, anode, were classed by us as internal to the topic of electricity, while externals included heat, power, flow, magnets, traffic, polymers, string, steam. This classification is, of course, subjective; another way of putting it is that the concepts were considered in relation to their standing in our, the judges', cognitive structures. Together we had little trouble in agreeing on each concept's place, but confess that the classification is rather arbitrary.

The numbers of links to each of the two classes of concepts were summed. The index calculated is the number of links to internal concepts divided by the total number of links, so it is a measure of degree of internal linking. It was preferred to the ratio of internal to external links because the distribution of the latter is more likely to be skewed.

Availability. Interviews of this type may not be an effective way of measuring availability, as the interviewer's part takes up more or less time depending on rapport with the respondent. We could have obtained an index of availability by dividing the extent score by the number of minutes in the interview, but chose not to.

Results.

The vectors of scores obtained on the several dimensions for the 28 respondents are shown in Table 1, and a matrix of correlations between all pairs of dimensions is shown in Table 2.

Most of our interest is in some of the correlations in Table 2. This interest is in two parts, one on the correlations among different dimensions within a topic, and the other on the correlations between the scores on the same dimension across topics.

Correlations between different dimensions. White (1979) argued that descriptive dimensions need not be orthogonal to be useful. Nevertheless, if there were high correlations of one dimension, such as Extent, with all

or several others the descriptive value of the set of dimensions would be reduced. As it happens, Extent correlates highly only with Degree of linking, so the other dimensions do add information to the description of cognitive structure.

The very high positive correlations between Extent and Degree of linking constitute a difficulty which is not resolved in this paper. The problem is that while some other algorithm could be applied to the numbers of links and concepts which would yield a smaller or even negative correlation, on theoretical grounds we would expect someone who has their knowledge well linked together to recall more of it. Therefore there should be a positive correlation between Extent and Degree of linking. Correlations of over 0.8, however, are too large to be useful. We conclude that our present conceptualization of Shape is unsatisfactory, and that it may be profitable to think about it in an entirely different way.

The high correlations between the Percentages of propositions, images, and episodes and the Variety index are a mathematical artefact. Among the other correlations Precision is strongly related to Accord with reality, which is comprehendable, and strangely it is negatively related to Percentage of images. Before making anything of the latter relation we should like to have it replicated in a further investigation. No sensible pattern can be discerned among the other correlations; their erratic nature and generally low values support the belief that each dimension other than Degree of linking adds something to the description of cognitive structure.

Correlations across topics. The most interesting finding of this study is the set of relatively high positive correlations for each dimension across the two topics. The topics were chosen to be unrelated, and there is no essential requirement that someone who knows a lot about electricity should

know a lot about gum trees. Yet such turns out to be the case. It could be, of course, not that considerable knowledge of current goes with considerable knowledge of eucalypts, but that the Extent score on both is determined largely by a single trait, the willingness to respond in an interview. That remains to be checked. Our impression, from observation of the respondents, is that that alternative explanation is not correct. It seems more reasonable to interpret the high positive correlation for Extent scores as an outcome of a set to learn, to acquire and store information.

The other set of correlations of interest to us is the one containing the percentages of the three types of element. The positive values for these imply the existence of a set to store information in one or other form. Respondent 13 in Table 1, for instance, has a remarkable propensity to recall episodes in both topics, while Respondent 9 has one for images. This discovery is likely to be important.

Despite the subjective nature of the classifying of concepts as internal or external, the moderate positive correlation between Percent internal connections across topics indicates a further trait which may be important in the theory of learning. The correlation is exemplified by Respondents 4 and 10, who have relatively low proportions of internal connections for both topics. Results obtained by Mayer and Greeno (1972) suggest that external connections are desirable.

Further work should investigate what underlies these characteristics of tendency to form external connections and preferences for either propositions, images, or episodes. They appear likely to be important in education.

Level of Knowledge

While opinions about how reasonable are the levels of the graduates' knowledge of the two topics are of no value to theory, they can affect

practice. The protocols have two notable features: great diversity, and a lower range reaching an abysmal level of ignorance. For electric current Extent scores range from 29 to 145, and for eucalypts from 13 to 110. The observation of such ranges in Extent emphasises the importance of considering prior knowledge before teaching new material. Respondent 3's knowledge of electric current and Respondent 27's knowledge of eucalypts are remarkably low for people who are certificated successes of our educational system. Of course, it could be argued that it is unreasonable to expect everyone to know a lot about any one topic chosen from the universe of knowledge. However, we would have expected science graduates to have a greater knowledge of electricity than was shown by at least a third of the respondents, and it concerns us that so many have been so untouched by the purpose of science teaching to make people more observant that they have never seen flowers on eucalypts and indeed are unsure of whether eucalypts do flower. It seems that some of the respondents have learned, from 16 years of formal education, to pass examinations but have missed other, more crucial parts of an education.

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Table 1

Dimension Scores for All Respondents

Respondent	Electric Current									Eucalypts								
	Extent	Precision	Accord with reality	% propositions	% images	% episodes	Variety	% internal	Linking	Extent	Precision	Accord with reality	% propositions	% images	% episodes	Variety	% internal	Linking
1	97	.93	.99	74	9	17	1.71	76	4.53	100	.99	.98	83	1	16	1.40	58	4.74
2	71	.83	.97	88	6	6	1.26	58	3.78	63	.96	1.00	81	5	14	1.47	61	4.62
3	29	.80	.96	86	0	14	1.31	52	3.40	28	.95	1.00	78	4	18	1.54	57	3.47
4	58	.90	.96	83	7	10	1.43	44	4.51	31	.87	.96	74	10	16	1.71	54	2.90
5	54	.91	.98	80	11	9	1.53	65	4.00	42	.97	.93	69	5	26	1.83	60	3.26
6	33	.89	.96	85	3	12	1.36	57	2.91	37	1.00	.93	79	5	16	1.55	58	3.22
7	31	.90	1.00	68	16	16	2.43	55	2.73	18	1.00	1.00	50	11	39	2.41	65	2.30
8	69	.85	.96	69	9	22	1.86	58	3.90	68	1.00	.96	78	7	15	1.58	64	4.46
9	59	.72	.91	73	17	10	1.75	70	3.67	15	.73	.91	73	20	7	1.72	87	3.25
10	92	.89	.97	81	3	16	1.48	52	4.60	55	.97	.97	73	2	25	1.68	43	4.00
11	68	.86	.95	85	4	11	1.35	61	3.73	33	.96	.92	76	3	21	1.61	57	3.11
12	35	.81	.93	78	11	11	1.61	57	3.17	34	.89	.93	82	3	15	1.43	55	3.74
13	49	.84	.94	63	8	29	2.05	61	2.98	68	.98	1.00	63	4	33	1.97	57	4.20
14	74	.80	.96	80	7	13	1.52	60	3.84	54	.98	1.00	80	2	18	1.50	60	3.81
15	145	.88	.98	90	3	7	1.23	58	6.04	110	.89	.93	82	5	13	1.44	48	4.99
16	44	.80	.83	80	9	11	1.52	44	3.23	22	.94	.88	77	5	18	1.61	60	2.26
17	59	.73	.98	68	29	3	1.83	60	3.51	32	.96	1.00	78	6	16	1.57	52	2.97
18	60	.84	.96	82	3	15	1.44	48	6.07	51	.88	1.00	49	12	39	2.46	36	5.04
19	54	.63	.83	74	7	19	1.70	45	3.62	25	.88	.94	68	12	20	1.94	51	2.80
20	111	.90	.97	77	8	14	1.62	52	5.53	109	.99	.99	79	2	19	1.52	37	4.61
21	39	.86	.82	72	8	21	1.76	49	4.16	46	.81	.97	78	7	15	1.57	55	3.64
22	46	.62	.64	85	11	4	1.36	53	2.80	27	.71	.86	78	7	15	1.57	55	2.40
23	108	.84	.90	71	6	23	1.78	47	4.48	106	.95	.99	77	5	18	1.61	45	4.82
24	67	.90	.91	91	3	6	1.20	48	5.60	23	.79	.95	83	9	9	1.42	56	4.11
25	64	.84	.82	77	6	17	1.60	61	3.34	40	.82	.88	85	3	13	1.35	61	4.06
26	89	.90	.89	80	8	12	1.52	60	3.79	68	.88	.88	87	4	9	1.30	56	3.75
27	31	.74	.83	74	16	10	1.71	53	3.10	13	.75	.63	62	23	15	2.17	59	2.88
28	33	.77	.92	79	12	9	1.53	49	2.89	28	.91	.86	79	11	11	1.54	61	2.87

Table 2

Correlations Between Dimensions

		ELECTRIC CURRENT								EUCALYPTS							
		Precision	Accord with reality	% propositions	% images	% episodes	Variety	% internal	Links	Extent	Precision	Accord with reality	% propositions	% images	% episodes	Variety	% internal	Links
ELECTRIC CURRENT	Extent	.36	.28	.17	-.26	.03	-.22	.19	.71	(.84)	.19	.26	.34	-.39	-.16	-.36	-.40	.69
	Precision		.63	.14	-.38	.21	-.03	.18	.44	.46	(.50)	.34	.09	-.44	.19	-.13	-.20	.46
	Accord with reality			-.02	-.06	.07	.10	.30	.33	.33	.72	(.53)	-.12	-.24	.30	.08	-.08	.40
	% propositions				-.58	-.62	-.92	-.19	.35	-.05	-.17	-.07	(.35)	-.17	-.29	-.35	-.18	.09
	% images					-.28	.56	.26	-.40	-.30	-.13	-.22	-.16	(.38)	-.07	.18	.35	-.44
	% episodes						.55	-.03	-.03	.34	.32	.29	-.26	-.16	(.41)	.24	-.12	.32
	Variety							.16	-.37	-.03	.21	.11	-.49	.21	.43	(.48)	.23	-.18
	% internal								-.13	.22	.15	.06	.19	-.18	-.11	-.22	(.47)	.22
	Links									.56	.01	.33	.03	-.12	.04	-.04	-.56	(.69)
EUCALYPTS	Extent										.42	.38	.28	-.53	.01	-.31	-.48	.80
	Precision											.58	-.04	-.60	.43	-.01	-.24	.23
	Accord with reality												-.00	-.55	.36	-.07	-.24	.40
	% propositions													-.51	-.83	-.99	.09	.18
	% images														-.06	.57	.37	-.36
	% episodes															.78	-.35	.02
	Variety																-.09	-.21
	% internal																	-.41